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Articles PAGE

The Hatchet Planimeter - - - - *John Satterly* 221

The Influence of Astronomy on Medicine - *J. B. Fraser* 244

A Simple Instrument for Projecting the Solar Disc *A. F. Miller* 248

Meetings of the Society - - - - - - 252

Notes from the Meteorological Service - - - - 259

Notes and Queries - - - - - - - 264

Astronomical Notes - - - - - - - 268

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THE HATCHET PLANIMETER

The use of planimeters is fairly common to-day and most students of mathematics and physics are familiar with the theory and practice of the common form of the polar planimeter, known as Amsler's planimeter. The theory is usually given in books on the calculus and handbooks of practical physics.* A lesser known planimeter is that of Prytz, also known as the *hatchet* planimeter. It consists of a metal rod, about a quarter of an inch in diameter, bent twice at right angles to form a long arm about ten inches long and two short arms about three inches long. One arm (fig. 1) is sharpened to a point P, and the other to a convex knife edge, or axe edge, K, in line with P. The distance from the point to the middle of the knife edge is usually made, for convenience, a definite distance, *e.g.* 10 inches or 25 centimetres. The rod must be stout and stiff enough to maintain this distance constant. When the instrument is in use the P-arm is held lightly

Vide, Williamson, *Integral Calculus;* Horsburgh, *Modern Instruments of Calculation;* Lipka, *Graphical and Mechanical Calculation.*

in a vertical position with the point P resting on the paper and the long arm stretching out in a horizontal position with the knife edge resting in easy contact upon the paper.

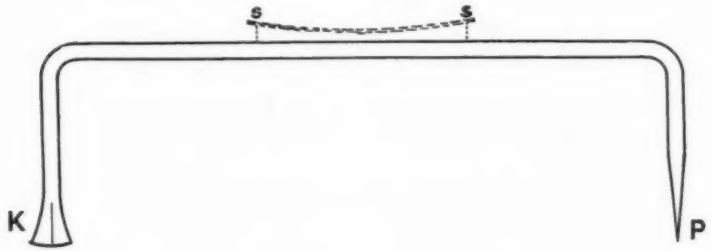

Fig. 1.

When P is made to trace any curve the knife edge K describes a curve such that PK is always tangential to the curve—in other words as P travels along any line K traces a "curve of pursuit."

In finding an area such as A (fig. 2) the position of the centre of area G is first approximately estimated and P placed upon it with the arm of the planimeter in a direction such as GK_1. The knife edge is gently pressed into the paper to form a light dent K_1, P is now made to pass by a straight line GB to the periphery, then

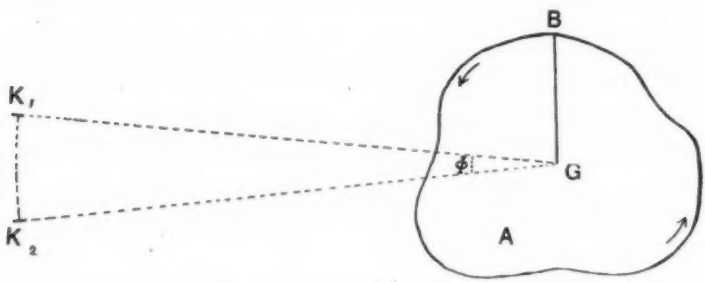

Fig. 2.

anticlockwise around the periphery, back to B and thence to G. The knife edge is then pressed into the paper to form another dent K_2.

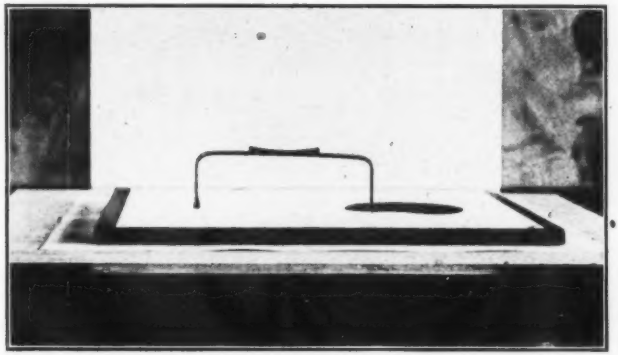

FIG. 3

The required area is given approximately by the product of the arm of the lever and the arc K_1K_2. As a check on K_1 K_2 the procedure may be repeated the tracer point being taken up GB, around the figure clockwise, and back to G. This should bring the knife edge back to K_1. Usually there is a slight discrepancy between the first and third positions and the average should be taken as K_1.

To facilitate the use of the instrument a short graduated scale may be soldered to the long arm of the planimeter so that it can be applied readily to measure K_1 K_2, and if this scale has been bent to an arc whose radius is the length of the planimeter so much the better*. This is indicated by the dotted curve SS in Fig. 1. The complete instrument as used in my laboratory at Toronto is shewn in the photograph (Fig. 3) standing on the drawing board ready for use on the area of the template indicated in black.

*See, however, a later remark on the relative merits of measuring the arc K_1K_2 or the chord K_1 K_2.

The theory of the instrument is not at all simple. It has been given by F. W. Hill in the *Philosophical Magazine* of October, 1894. Hill states that the expression for the area in terms of the length of the arm and the angle K_1GK_2 (Fig. 2) is complex and in general can only be obtained in the form of an infinite series.

His proof is difficult to follow and I have here attempted to simplify it where it seems necessary.

The first step in Hill's proof is: Let the tracer point P move a distance r along a straight line OX (Fig. 4) so that the initial and final positions of the rod are P_1K_1 and P_2K_2.

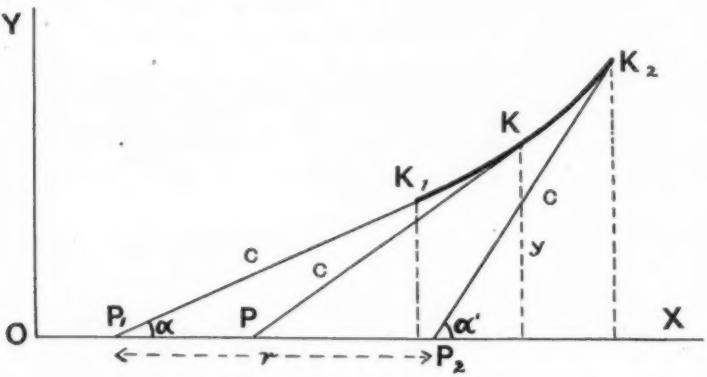

Fig. 4.

Let α, α', be the initial and final inclinations of the rod to OX. Let c be the length of the arm PK. Then shall

$$\tan\frac{\alpha'}{2} = e^{\frac{r}{c}} \tan\frac{\alpha}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

This formula is proved as follows: From the figure we see that in all positions of the rod, $y = c \sin \alpha$, where, for the moment, α is the general value of the slope of the arm to O X.

But $\tan \alpha = \frac{dy}{dx}$,

and therefore $= c \cos \alpha \frac{d\alpha}{dx}$

$$\therefore dx = c \frac{\cos^2 \alpha}{\sin \alpha} d\alpha$$

$$= c \frac{1-\sin^2 \alpha}{\sin \alpha} d\alpha$$

$$= c\left(\frac{1}{\sin \alpha} - \sin \alpha\right) d\alpha$$

Integrating we get

$$x = c \cos \alpha + c \log \tan \frac{\alpha}{2} + \text{Constant}$$

Going to the limits x, x', corresponding to K_1, K_2 we get

$$x' - x = c (\cos \alpha' - \cos \alpha) + c \log \frac{\tan \frac{\alpha'}{2}}{\tan \frac{\alpha}{2}}$$

Now $r = (x' - c \cos \alpha') - (x - c \cos \alpha)$

$$= (x' - x) + c(\cos \alpha - \cos \alpha')$$

$$= c \log \frac{\tan \frac{\alpha'}{2}}{\tan \frac{\alpha}{2}}$$

whence $e^{\frac{r}{c}} = \frac{\tan \frac{\alpha'}{2}}{\tan \frac{\alpha}{2}}$

which is equation (1)

Taking two positions of the planimeter near one another, let α, $\alpha + d\alpha$ (Fig. 5) be the inclinations of the planimeter arm to the fixed line along which the tracer point travels, then if dr is the distance between the corresponding two positions of the tracer-point we see that

$$c d\alpha = dr \sin \alpha$$

$$\text{or } \frac{d\alpha}{\sin \alpha} = \frac{dr}{c} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

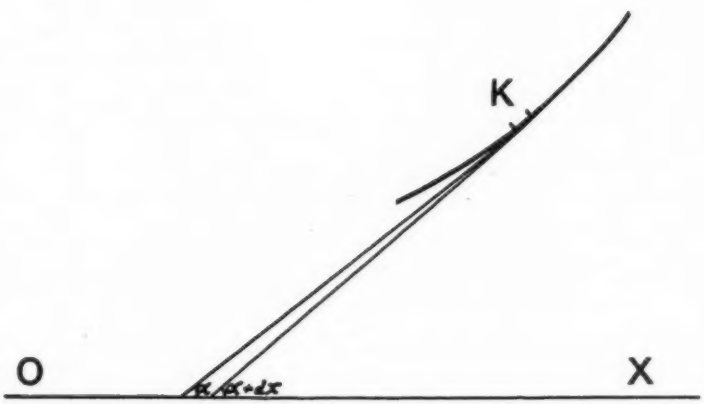

Fig. 5.

Again taking logarithms of the two sides of equation (1) we get

$$\log \tan \frac{a'}{2} = \frac{r}{c} + \log \tan \frac{a}{2}$$

and by differentiating

$$\frac{1}{\tan \frac{a'}{2}} \cdot \sec^2 \frac{a'}{2} \cdot \frac{1}{2} \cdot \frac{da'}{dr} = \frac{1}{c} + \frac{1}{\tan \frac{a}{2}} \cdot \sec^2 \frac{a}{2} \cdot \frac{1}{2} \cdot \frac{da}{dr},$$

$$\text{or } \frac{1}{2 \sin \frac{a'}{2} \cos \frac{a'}{2}} \cdot \frac{da'}{dr} = \frac{1}{c} + \frac{1}{2 \sin \frac{a}{2} \cos \frac{a}{2}} \cdot \frac{da}{dr},$$

$$\text{whence } \frac{da'}{\sin a'} = \frac{dr}{c} + \frac{da}{\sin a} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Divide the area to be measured up into elementary triangles having their vertices at a point O within the area and having elements of the perimeter as their bases. The Triangle OPQ (Fig. 6) is one such triangle. The tracer point may be supposed to move around each of these triangles in turn so that each radius vector (OP, OQ, etc.) is traversed twice, in opposite directions. Starting with the tracer point at O and the rod of the planimeter in position 1,

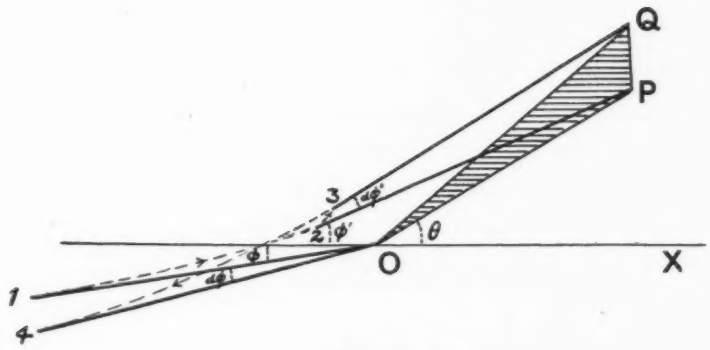

Fig. 6.

the tracer point moves up to P then to Q and back to O the rod taking up successively the positions 1, 2, 3, 4. Taking any fixed line OX let the angles of inclination of OP, OQ, to this line be θ, $\theta + d\theta$ and the angles of inclination of the rod in the positions 1, 2, 3, 4, be ϕ, ϕ', $\phi' + d\phi'$, $\phi + d\phi$.

Let OP$=r$, OQ$=r+dr$

then by equation (1) and Fig. 7 we see that, for the motion from O to P

$$\tan\frac{\theta-\phi'}{2} = e^{-\frac{r}{c}}\tan\frac{\theta-\phi}{2} \quad \ldots\ldots\ldots (4)$$

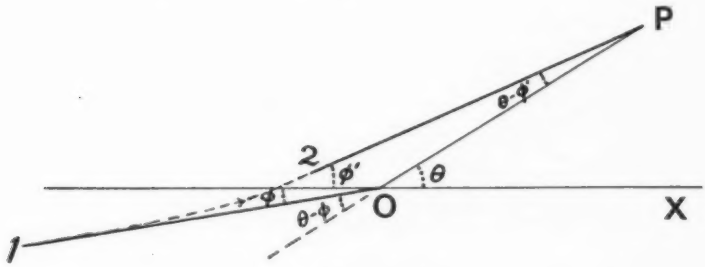

Fig. 7

and for the motion from Q to O

$$\tan \frac{(\theta+d\theta)-(\phi'+d\phi')}{2} = e^{-\frac{r+dr}{c}} \tan \frac{(\theta+d\theta)-(\phi+d\phi)}{2} \quad \ldots\ldots(5)$$

From these equations and equation (3) we get

$$\frac{d\theta-d\phi'}{\sin(\theta-\phi'} = -\frac{dr}{c} + \frac{d\theta-d\phi}{\sin(\theta-\phi)} \quad \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Take now the motion of the tracer point from P to Q. Let ψ (Fig. 8) be the angle between OP and the element of the peri-

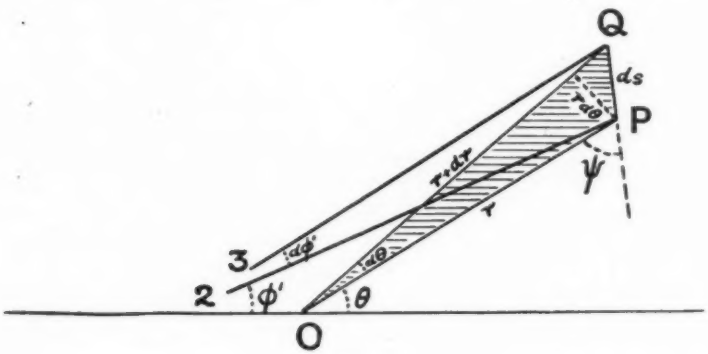

Fig. 8.

meter PQ: When the tracer point is at P the inclination of the planimeter arm to PQ is $\psi+\theta-\phi'$ and when the tracer point is at Q the inclination is $\psi+\theta-\phi'-d\phi'$. Denoting the length of PQ by ds we get by (2)

$$\frac{d\phi'}{\sin(\psi+\theta-\phi')} = \frac{ds}{c}$$

$$\therefore c\,d\phi' = ds\,[\sin\psi\cos(\theta-\phi')+\cos\psi\sin(\theta-\phi')]$$

But $ds\sin\psi = rd\theta$ and $ds\cos\psi = dr$

$$\therefore c\,d\phi' = rd\theta\cos(\theta-\phi')+dr\sin(\theta-\phi') \quad \ldots\ldots\ldots(7)$$

Writing (6) as

$$\frac{cd\theta - cd\phi'}{\sin(\theta-\phi')} = -dr + \frac{c(d\theta - d\phi)}{\sin(\theta-\phi)}$$

and now substituting for $cd\phi'$ from equation (7) we get

$$\frac{cd\theta - rd\theta\cos(\theta-\phi') - dr\sin(\theta-\phi')}{\sin(\theta-\phi')} = -dr + \frac{c(d\theta-d\phi)}{\sin(\theta-\phi)}$$

$$\text{or } \frac{cd\theta - rd\theta\cos(\theta-\phi')}{\sin(\theta-\phi')} - dr = -dr + \frac{c(d\theta-d\phi)}{\sin(\theta-\phi)}$$

Cancelling the dr's and transposing we get

$$\frac{d\theta - d\phi}{\sin(\theta-\phi)} = \frac{d\theta - \frac{r}{c}d\theta\cos(\theta-\phi')}{\sin(\theta-\phi')}$$

$$= \frac{d\theta\left(\cos^2\frac{\theta-\phi'}{2} + \sin^2\frac{\theta-\phi'}{2}\right) - \frac{r}{c}d\theta\left(\cos^2\frac{\theta-\phi'}{2} - \sin^2\frac{\theta-\phi'}{2}\right)}{2\sin\frac{\theta-\phi'}{2}\cos\frac{\theta-\phi'}{2}}$$

$$= \frac{d\theta\left(1-\frac{r}{c}\right)\cos^2\frac{\theta-\phi'}{2}}{2\sin\frac{\theta-\phi'}{2}\cos\frac{\theta-\phi'}{2}} + \frac{d\theta\left(1+\frac{r}{c}\right)\sin^2\frac{\theta-\phi'}{2}}{2\sin\frac{\theta-\phi'}{2}\cos\frac{\theta-\phi'}{2}}$$

$$= \frac{d\theta}{2}\left(1-\frac{r}{c}\right)\cot\frac{\theta-\phi'}{2} + \frac{d\theta}{2}\left(1+\frac{r}{c}\right)\tan\frac{\theta-\phi'}{2} \quad \ldots\ldots\ldots (8)$$

Now since by equation (4)

$$\tan\frac{\theta-\phi'}{2} = e^{-\frac{r}{c}}\tan\frac{\theta-\phi}{2}$$

and therefore the reciprocal

$$\cot\frac{\theta-\phi'}{2} = e^{\frac{r}{c}}\cot\frac{\theta-\phi}{2}$$

We therefore get

$$\frac{d\theta-d\phi}{\sin(\theta-\phi)} = \frac{d\theta}{2}\left(1-\frac{r}{c}\right)e^{\frac{r}{c}}\cot\frac{\theta-\phi}{2} + \frac{d\theta}{2}\left(1+\frac{r}{c}\right)e^{-\frac{r}{c}}\tan\frac{\theta-\phi}{2}$$

$$\therefore d\theta - d\phi = 2\sin\frac{\theta-\phi}{2}\cos\frac{\theta-\phi}{2}\left[\frac{d\theta}{2}\left(1-\frac{r}{c}\right)e^{\frac{r}{c}}\cot\frac{\theta-\phi}{2} + \frac{d\theta}{2}\left(1+\frac{r}{c}\right)e^{-\frac{r}{c}}\tan\frac{\theta-\phi}{2}\right]$$

$$= d\theta\left(1-\frac{r}{c}\right)e^{\frac{r}{c}}\cos^2\frac{\theta-\phi}{2} + d\theta\left(1+\frac{r}{c}\right)e^{-\frac{r}{c}}\sin^2\frac{\theta-\phi}{2}$$

$$= d\theta\left(1-\frac{r}{c}\right)e^{\frac{r}{c}}\left(\frac{1+\cos(\theta-\phi)}{2}\right) + d\theta\left(1+\frac{r}{c}\right)e^{-\frac{r}{c}}\left(\frac{1-\cos(\theta-\phi)}{2}\right)$$

$$= \tfrac{1}{2}\,d\theta\left[\left(1-\frac{r}{c}\right)e^{\frac{r}{c}} + \left(1+\frac{r}{c}\right)e^{-\frac{r}{c}}\right] + \tfrac{1}{2}\,d\theta\left[\left(1-\frac{r}{c}\right)e^{\frac{r}{c}} - \left(1+\frac{r}{c}\right)e^{-\frac{r}{c}}\right]\cos(\theta-\phi) \quad \ldots\ldots\ldots (9)$$

Taking the first expression within the square brackets on the right hand side of this equation we get, if $r<c$

$$\left(1-\frac{r}{c}\right)\left(1+\frac{r}{c}+\frac{r^2}{2c^2}+\frac{r^3}{6c^3}+\frac{r^4}{24c^4}+\ldots\ldots\right) + \left(1+\frac{r}{c}\right)\left(1-\frac{r}{c}+\frac{r^2}{2c^2}-\frac{r^3}{6c^3}+\frac{r^4}{24c^4}-\ldots\ldots\right)$$

$$= 1+\frac{r}{c}+\frac{r^2}{2c^2}+\frac{r^3}{6c^3}+\frac{r^4}{24c^4}+\frac{r^5}{120c^5}+\frac{r^6}{720c^6}+\ldots\ldots$$

$$-\frac{r}{c}-\frac{r^2}{c^2}-\frac{r^3}{2c^3}-\frac{r^4}{6c^4}-\frac{r^5}{24c^5}-\frac{r^6}{120c^6}-\ldots\ldots$$

$$+1-\frac{r}{c}+\frac{r^2}{2c^2}-\frac{r^3}{6c^3}+\frac{r^4}{24c^4}-\frac{r^5}{120c^5}+\frac{r^6}{720c^6}-\ldots\ldots$$

$$+\frac{r}{c}-\frac{r^2}{c^2}+\frac{r^3}{2c^3}-\frac{r^4}{6c^4}+\frac{r^5}{24c^5}-\frac{r^6}{120c^6}-\ldots\ldots$$

$$= 2-\frac{r^2}{c^2}-\frac{r^4}{4c^4}-\frac{r^6}{72c^6}+\ldots\ldots$$

$$= 2\left[1-\frac{r^2}{2c^2}-\frac{r^4}{8c^4}-\frac{r^6}{144c^6}-\ldots\ldots\right]$$

The second expression in square brackets on the right hand side of the equation gives

$$\left(1-\frac{r}{c}\right)\left(1+\frac{r}{c}+\frac{r^2}{2c^2}+\frac{r^3}{6c^3}\cdots\cdots\right)-\left(1+\frac{r}{c}\right)\left(1-\frac{r}{c}+\frac{r^2}{2c^2}-\frac{r^3}{6c^3}+\cdots\cdots\right)=2\left[-\frac{r^3}{3c^3}-\frac{r^5}{30c^5}-\cdots\cdots\cdots\cdots\right]$$

Therefore

$$d\theta-d\phi=d\theta\left[1-\frac{r^2}{2c^2}-\frac{r^4}{8c^4}-\frac{r^6}{144c^6}-\cdots\cdots\right]-d\theta\left[\frac{r^3}{3c^3}+\frac{r^5}{30c^5}+\cdots\cdots\right]\cos(\theta-\phi)$$

$$\therefore -d\phi=-d\theta\left[\frac{r^2}{2c^2}+\frac{r^4}{8c^4}+\frac{r^6}{144c^6}+\cdots\cdots\right]-d\theta\left[\frac{r^3}{3c^3}+\frac{r^5}{30c^5}+\ldots\right]\cos(\theta-\phi)$$

$$\text{or } c^2d\phi=\frac{r^2d\theta}{2}+\frac{r^4}{8c^2}d\theta+\frac{r^6}{144c^4}d\theta+d\theta\left[\frac{r^3}{3c}+\frac{r^5}{30c^3}+\cdots\right]\cos(\theta-\phi) \quad \ldots\ldots\ldots\ldots(10)$$

The $d\phi$ here given is the change in direction of the planimeter arm when the tracer point has completed the circuit of the elementary triangle OPQ. Repeating the process for all the elementary triangles into which the area is divided we get

$$c^2\int d\phi=\int\tfrac{1}{2}r^2d\theta+\frac{1}{8c^2}\int r^4d\theta+\frac{1}{144c^4}\int r^6d\theta+\cdots\cdots\cdots+\frac{1}{3c}\int r^3\cos(\theta-\phi)\,d\theta+\frac{1}{30c^3}\int r^5\cos(\theta-\phi)\,d\phi+\cdots\cdots$$

The integrations of θ extend through two right angles and if Φ is the angle between the initial and final positions of the planimeter arm and A is the area required this equation becomes

$$c^2\Phi=A+\frac{1}{8c^2}\int r^4d\theta+\frac{1}{144c^4}\int r^5d\theta+\cdots\cdots\cdots+\frac{1}{3c}\int r^3\cos(\theta-\phi)\,d\theta+\frac{1}{30c^4}\int r^5\cos(\theta-\phi)\,d\theta+\cdots\cdots(11)$$

If the average value of r is very small in comparison with c then all the terms on the right hand after the first become negligible and therefore

$$c^2\Phi = A \qquad \ldots\ldots\ldots(12)$$

$$\text{or } A = c \times c\Phi = c \times \text{arc } K_1K_2 \qquad \ldots\ldots\ldots(13)$$

which is the formula that was quoted above, and which may, as we see, be employed by using a planimeter whose size is properly related to the dimensions of the figure whose area is to be obtained.

If the length of the planimeter is not large in comparison with the breadth of the figure it is important to inquire into the relative magnitudes of the other terms on the right hand side of equation (11) and to see if any of them may be decreased by a proper choice of origin and initial positions of the first radius vector and arm of the planimeter.

Taking the term $\frac{1}{8c^2}\int r^4 d\theta$ this may be written $\frac{1}{2c^2}\int \tfrac{1}{2}r^2 d\theta . \frac{r^2}{2}$ which is $\frac{Ak^2}{2c^2}$ where Ak^2 is the moment of inertia about an axis through O at right angles to the area. This is the so-called polar moment of inertia. Its value is least when the axis goes through the centre of surface of the area or the centre of gravity of a lamina occupying the area, which point is also called the centroid.

Taking the term $\frac{1}{144c^4}\int r^6 d\theta$, this is seen to be less than $\frac{2}{144c^4}\int a^4 . \frac{r^2 d\theta}{2}$ where a is the greatest value of r. So that this term is less than $\frac{2A}{144}\left(\frac{a}{c}\right)^4$ which, if $\frac{a}{c}$ is a little less than unity, is less than one per cent. of A.

It now remains to evaluate the terms containing $\cos(\theta-\phi)$. The first term is the most important. If the area of the curve is less than that of a square whose side is the length of the planimeter arm the greatest value of Φ is one radian (see equations 11 and 12). Expanding the first cosine term we get

$$\frac{1}{3c}\int r^3 \cos(\theta-\phi)\, d\phi = \frac{1}{3c}\int r^3 \left[\cos\theta\cos\phi + \sin\theta\sin\phi\right] d\theta$$

$$= \frac{1}{3c}\int r^3 \left[\cos\theta\left(1-2\sin^2\frac{\phi}{2}\right)+\sin\theta\sin\phi\right]d\theta$$

$$= \frac{1}{3c}\int r^3\cos\theta\,d\theta - \frac{2}{3c}\int r^3\cos\theta\sin^2\frac{\phi}{2}\,d\theta + \frac{1}{3c}\int r^3\sin\theta\sin\phi\,d\theta$$

$\sin\phi$ is less than ϕ so that the last term will not exceed $\frac{1}{3c}\int r^3\phi\sin\theta\,d\theta$ and $\sin\frac{\phi}{2}$ will be less than $\frac{\phi}{2}$ so that the second term will be less than $\frac{1}{6c}\int r^3\phi^2\cos\theta\,d\theta$.

Therefore

$$\frac{1}{3c}\int r^3\cos(\theta-\phi)\,d\theta < \frac{1}{3c}\int r^3\cos\theta\,d\theta + \frac{1}{3c}\int r^3\phi\sin\theta\,d\theta - \frac{1}{6c}\int r^3\phi^2\cos\theta d\theta$$

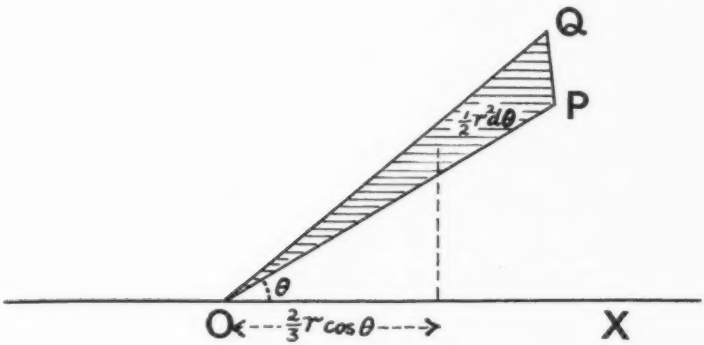

Fig. 9.

Let the initial position of the planimeter arm be taken as the axis of x then taking an elementary triangle as shown in Fig. 9 it is evident that

$$\tfrac{1}{3}r^3\cos\theta\,d\theta = \frac{r^2d\theta}{2}\cdot\frac{2}{3}\,r\cos\theta$$

=area of triangle OPQ multiplied by the distance of its centre of area from O measured parallel to the axis of x. Extending this to the whole figure we get

$$\frac{1}{3c}\int r^3\cos\theta\,d\theta = \frac{1}{c}\,A\bar{x}$$

where $\bar{x}$ is the x co-ordinate of the centroid of the figure measured from an origin at O. The second and third terms diminish as $\left(\frac{a}{c}\right)$ diminishes and as they are also oscillating quantities their integrals may be neglected.
Therefore we write

$$c^2\Phi = A + \frac{Ak^2}{2c^2} + \frac{A\bar{x}}{c} + \frac{P}{c^3} \quad \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

where P is very small
If the vertex O is also the centroid, $\bar{x}$ is zero, and if the moment of inertia about the axis through the centroid at right angles to the area is denoted by $A\,\rho^2$, $A\,\rho^2$ is the least value of Ak^2.
$\therefore$ in this case

$$\therefore c^2\Phi = A + \frac{A\,\rho^2}{2c^2} \text{ very nearly}$$

$$= A\left(1 + \frac{\rho^2}{2c^2}\right) \quad ,, \quad \ldots\ldots\ldots\ldots (15)$$

so that the error made in the area by taking $c^2\Phi$ for its value is an overestimate of the order of $\frac{\rho^2}{2c^2} \times 100$ per cent.

If it is not possible to pick out exactly the centroid as the starting point of the plainmeter the area may be taken first with the arm of the planimeter stretching out to the left of the figure and then repeated with the arm stretching out to the right. This modification reverses the sign of c so that

$$c^2\Phi_1 = A + \frac{Ak^2}{2c^2} + \frac{A\bar{x}}{c} + \frac{P}{c^3}$$

$$c^2\Phi_2 = A + \frac{Ak^2}{2c^2} - \frac{A\bar{x}}{c} - \frac{P}{c^3}$$

$$\therefore \frac{c^2}{2}\left(\Phi_1 + \Phi_2\right) = A\left(1 + \frac{k^2}{2c^2}\right) \ldots\ldots\ldots\ldots (16)$$

Instead of reversing the direction of the arm of the lever it may be more convenient to turn the paper carrying the figure through two right angles, and now repeat the process with the arm of the planimeter still out to the left.

It is hardly possible even with the greatest of care to measure the distance between two dents to less than ¼ mm and even if it were so the first and third positions of K_1 (see Fig. 2 and the following text) often differ by more than this amount. The possible error may therefore be taken as 1/8 mm.

The planimeters I use in Toronto have an arm of 250 millimetres, and if there is a possible error in $c\Phi$ (=the distance between K_1 and K_2) of about 1/8 mm the error in $c^2\,\Phi$ will be about 30 sq. millimetres. If this unavoidable error is greater than $\frac{Ak^2}{2c^2}$ the latter may be neglected. This point will be taken up later.

Two conclusions given by Hill are, with slight variations:

(1) Using a 250 mm planimeter if the origin be near the centre of area and the greatest breadth of the figure be less than 80 mms the formula $c^2\Phi = A$ gives the area as accurately as the nature of the instrument will allow.

(This is obtained by putting $\frac{Ak^2}{2c^2} = 30$ mm^2 and taking a circle as the type of figure, for a circle is that figure which for the greatest breadth has the greatest area. If R is the radius of the circle $k^2 = \frac{R^2}{2}$ and $A = \pi R^2$

$$\therefore \text{ putting } \frac{\pi R^2}{2(250)^2} \cdot \frac{R^2}{2} = 30$$

we get $R = 40$ mms. nearly).

(2) If the area does not exceed 142 sq. cms it is not necessary to measure the arc $K_1\,K_2$; the chord may be measured instead. (This is obtained by noting that the arc exceeds the chord by $250\left(\phi - 2\sin\frac{\phi}{2}\right)$mm. If this distance is not to exceed 1/8 mm,, ϕ must not exceed 13° or .227 radian, or the area must not exceed 142 sq. cms.).

Practical Tests

In the experimental tests various figures were chosen and their areas found (1) by calculation (if possible) (2) by an Amsler planimeter, (3) by the hatchet planimeter.

The hatchet planimeter had an arm of 24.9 cms. and it carried a steel scale graduated to half mms. and bent to the right curvature.

REGULAR FIGURES

(1) *Circles.* A series of circles of radii nearly 2, 3, 4, 5, 7, 9, and 11 cms. was drawn with a common centre and the areas of the circles found by taking the origin at the centre. The planimeter was used with the arm pointing out to the left. (This is the most convenient direction.) In each case the circle was traced (1) anti-clockwise, (2) clockwise. and the average taken a described above. It is important to hold the P-arm of the planimeter lightly so as not to influence the direction of motion of the hatchet edge. Otherwise just ordinary care was taken.

Table I Circles Origin taken at Centre.

RADIUS Cm	Area by calculation Cm^2	Area by Amsler's planimeter taken once cm^2	Error with Amsler's expressed as percentage	Area by hachet planimeter cm^2	Error cm^2	Error expressed as percentage	Percentage error calculated by $\frac{k^2}{2c^2}$
2.02	12.82	12.6	−1	12.9	.08	+½	1/6
3.01	28.46	28.3	−½	28.2	−.26	−1	1/3
4.00	50.25	50.6	+7/10	51.0	.75	+1½	2/3
4.98	77.89	78.9	+1/8	79.7	1.8	+2	1
6.98	153.1	154.8	+1	156.9	3.8	+2½	2
9.02	255.6	256.9	+½	265.8	10.2	+4	3
11.00	380.1	382.3	+½	402.2	22.1	+6	5

The agreement of the last two columns is fairly good. If in the case of the larger circles the chord $K_1 K_2$ is measured instead of the arc the error of the hatchet planimeter result is decreased. Thus in the case of the largest circle the chord $K_1 K_2$ multiplied by the arm gives 397 cm^2.

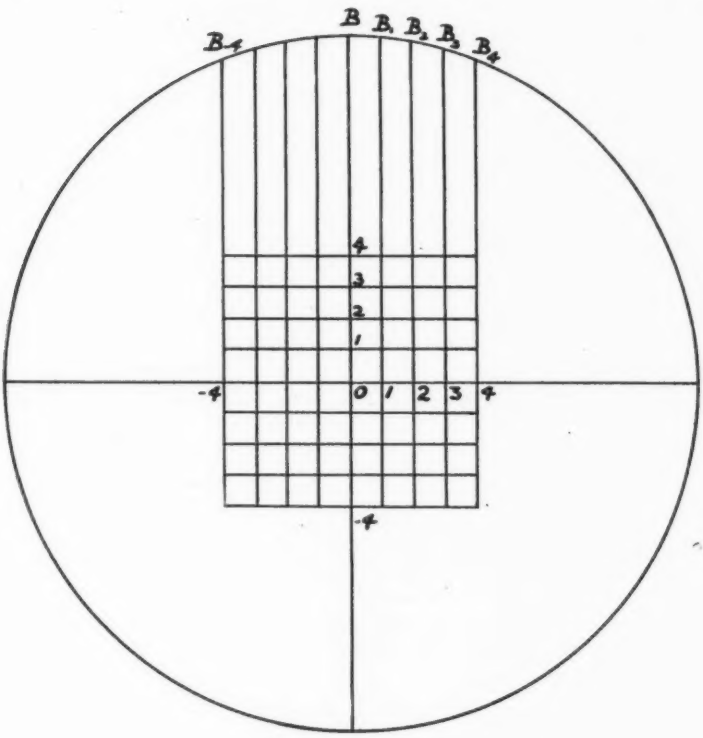

Fig. 10.

An attempt was made to see what error was introduced if the starting point was not at the centre of gravity. The circle of radius 9 cm. was taken and a gridiron pattern drawn as shown in Fig. 10 served to give starting points at centimetre intervals. In each case for the point chosen the vertical line through that point was traced up to the circumference. The arm of the planimeter was directed to the left. In some cases the readings were not duplicated. The results are given in the Table.

TABLE II Circle (Radius 9.02 cm.)

Starting from centre – Area = 265.8 cm².

Starting from:

Points on line drawn up from centre along axis of y		Points on line drawn out from centre at 45° to axes of x and y		Points on line drawn out from centre along axis of x	
Point	Area	Point	Area	Point	Area
x, y		x, y		x, y	
0, 1	264	1, 1	254	1, 0	255
0, 2	263	2, 2	243	2, 0	246
0, 3	263	3, 3	234	3, 0	234
0, 4	263	4, 4	226½	4, 0	224
...	...	−4+4	312	....	...
0, 9	284	−4−4	320	9, 0	182
		+4−4	227		

It will be seen by comparison with Table I that the points 1, 1 and 1, 0 give better results than the centre of the circle. So that an error in locating the centroid made in the direction of these points would improve the result. An error made in the direction of the axis of y introduces no additional error over that obtained from the centre until the origin is taken far out.

The reading for the point −2, 0 corresponds to a reading taken at the point 2, 0 with the arm of the planimeter reversed. Hence the average of readings taken at 2, 0 and −2, 0 should eliminate the x term.

The reading at 2, 0 was 246 sq. cm.
The reading at −2, 0 was 286 sq. cm.

Average = 266 sq. cm.

which is still in excess of the true area but in agreement with the result obtained with the origin at the centre ($Ak^2/2c^2$ for an origin 2 cms from the centre = 9 sq. cm.)

Attention may be called to the results taken at the corner points 4, 4; −4,4; −4−4; 4, −4. The blending of the results at 4.4 and −4, 4 should eliminate the $\bar{x}$ term in equation (14), similarly for the results at −4,−4, and 4,−4. The average of 226½ and 312 is 269 and that of 320 and 227 is 273. Both means are high by about six per cent. However in an area of this size it is hardly likely that the estimated centroid would be farther away from the centre than two cms.

(2) *A Rectangle.* A rectangular tinplate template was tried. It had a hole at the centre of gravity, and could be fastened to the drawing board by drawing-pins through two other holes.

All readings with the hatcher planimeter started from the centr of gravity and the tracer point was kept against the edge of the template as it travelled around it; this keeps the point from wandering from the right path. Two readings, clockwise, gave arcs of 4.03 and 3.92, and two, anti-clockwise, gave arcs of 4.07 and 3.91. The mean of the four is 3.98 giving an area of 99.1 cm². A tracing by the Amsler planimeter gave 95.8 cm². However the Amsler tracer needle is thinner than the arm of the hatchet planimeter so that the Amsler point traces a slightly smaller area. On removing the template and taking the Amsler around on the scratch made on the paper by the point of the hatchet planimeter the reading went up to 96.0 cm². The area of the rectangle traced by the tracer point was 12.5 cm x 7.7. cm = 96.3 cm². The error of the hatchet result was therefore 2.8 cms² too great. The formula tells us the excess should be $\frac{Ak^2}{2c^2}$. The moment of inertia of the rectangle about the polar axis through the centroid is

$$A\left(\frac{12.5^2+7.7^2}{12}\right)=A\times 17.9$$

$$\therefore \frac{Ak^2}{2c^2}=\frac{96\times 17.9}{2\times(24.9)^2}=1.4 \text{ cm.}^2$$

No error was made on account of the $\bar{x}$ term so that here the P term must be responsible for the excess error.

Irregular Figures

(1) *An Indicator Diagram.* A metal template was used. Its shape is shown in Fig. 11, where G is the centre of gravity (found by suspension and a plumb line). The template was fastened down to the drawing board. B G B^1 is a straight line. With

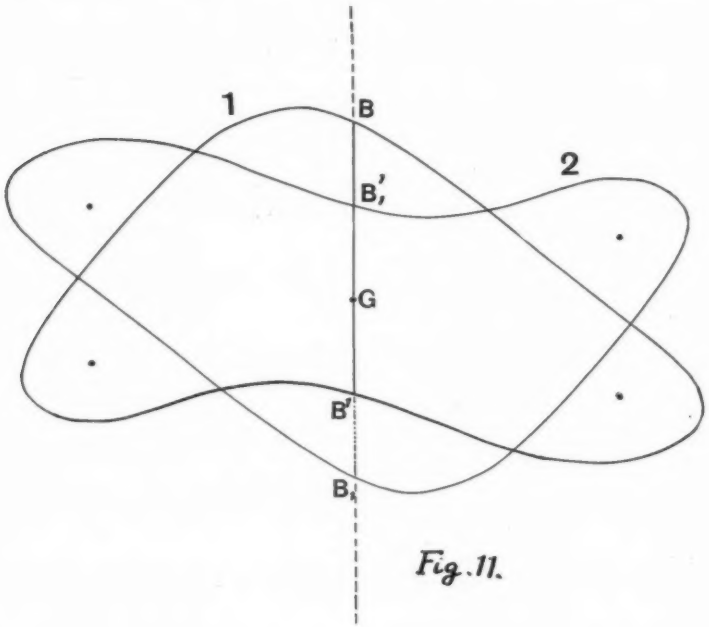

Fig. 11.

the template in position (1) and the planimeter arm extending to the left readings were taken

(*a*) from G to B around clockwise and back to G. Mean arc of two readings = 3.10 cm.

(*b*) from G to B around anticlockwise and back to G. Mean of two readings = 3.37 cm.

(*c*) from G to B^1 around clockwise and back to G. Mean of two readings = 3.17 cm.

(*d*) from G to B^1 around anticlockwise and back to G. Mean of two readings = 3.32 cm.

Keeping G fixed, the template was turned in its own plane through two right angles to position (2). B goes to B_1 and B^1 to B_1'. The readings were again taken. This set corresponds to a repetition with the template in position (1) and the arm pointing out to the right, so that a combination of the two sets should eliminate any error due to inaccuracy in the x component of the centroid.

(*a*) Two readings from G to B_1' and around clockwise gave as mean 3.32 cms.

(*b*) Two readings from G to B_1' and around anticlockwise gave as mean 3.34 cms.

(*c*) Two readings from G to B_1 and around clockwise gave as mean 3.32 cms.

(*d*) Two readings from G to B_1 and around anticlockwise gave as mean 3.52 cms.

The mean of all the readings = 3.31 and 3.31 x 24.9 = 82.4 cm^2.

The Amsler passed around the template twice gave clockwise 81.1 cm^2, and anticlockwise 81.7 cm^2. When the template was removed and the Amsler taken around the scratch made by the point P of the hatchet the readings for position (1) were 81.4 cm^2 and 82.1 cm^2 and for position (2) 81.3 cm^2 and 81.8 cm^2, a mean of 81.6 cm^2. Comparing the Hatchet result of 82.4 with the Amsler's result of 81.6 we see that the error is less than 1%. The greatest length of the figure was 16.5 cm. and the least 6.6 cms.

(2) *Figure traced from a hand.* As before a metal template was used (Fig. 12) and its centroid G found by suspension. The area was measured twice (*a*) template on paper with thumb to right, mean of two results = 151.3 cm^2, (*b*) thumb to left, mean of two results = 150.6 cm^2. Mean 151.0 cm^2.

Area by Amsler's planimeter = 146.8 cm^2.

Error = 4 cm^2.

Calculation of the value of $\frac{Ak^2}{2c^2}$:

To get k^2 a hole O was punched through the tip of the middle finger and the template hung from a needle support and set vibrat-

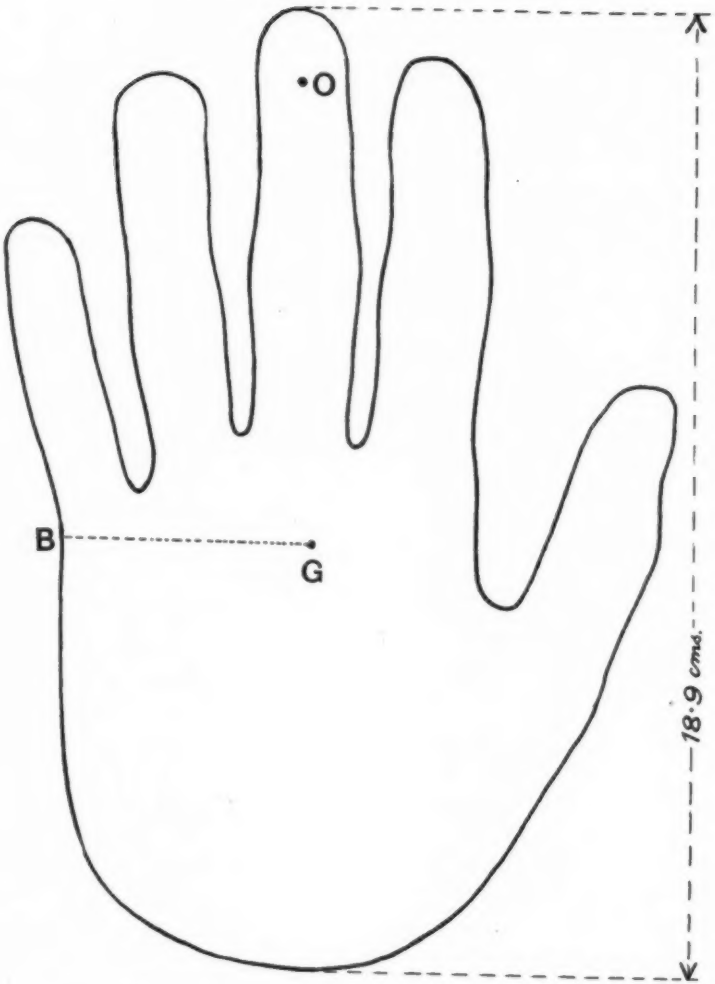

Fig. 12.

ing in its own plane. It made 42 vibrations in 30 seconds. The distance from the point of support to the centroid was 9.15 cm.

Therefore $\frac{30}{42} = 2\pi\sqrt{\frac{9.15 + \frac{k^2}{9.15}}{981}}$ whence $k^2 = 9.15 \times 3.5\,\text{cm}^2$

$\therefore \frac{Ak^2}{2c^2} = \frac{147 \times 9.15 \times 3.5}{2 \times (24.9)^2} = 3.7\ \text{cm}^2$ which considering the slight differences in area which the two instruments trace is a very good confirmation of the 4 cm^2 error mentioned above.

SUMMARY: It has been shown now that the Hatchet planimeter is an instrument which is quite useful for the estimation of areas.

In the Physics Laboratory at Toronto I have in use about fifty of these planimeters. The students work on areas of maps of countries, areas of indicator diagrams, with subsequent calculation of horse power, areas of ellipses, and areas of various shapes made up of tin-plate templates. The templates are very useful with large classes because the demonstrators can easily keep a record of their areas and they serve as standards. At present we use only one size of planimeter—a 25 cm. arm—but of course if larger areas were wanted a larger instrument would be used. One great merit of the instrument is its cheapness. Without the scale its cost need not exceed 10 cents. With the mounted scale it might be one dollar.

THE INFLUENCE OF ASTRONOMY ON MEDICINE

By J. B. Fraser, M.D.

An interesting fact in connection with the history of medicine is the close relationship of the two sciences during the middle ages, and the fact that even two hundred years ago Dr. Richard Mead issued a work called, "Treat'es of the Power and Influence of the Sun and Moon on Human Bodies", in which he took the ground that most diseases had their origin in celestial influences. Hippocrates believed that the moon had a marked influence on disease and his belief was echoed by Dr. R. Brooks, who about 1751 issued a chart showing the orbit of the moon divided into 360 degrees; and he contended that, beginning with the onset of the disease, the days corresponding to 45°, 90°, 135°, 180°, 225°, 270°, 315° and 360° were critical days and demanded an extra amount of attention.

That the weather has an influence on some diseases is a well known fact, examples of which are sunstroke, heat-stroke, sun-blisters, diarrhoeas and dysenteries in summer; pneumonias and bronchial troubles in winter; and extra rheumatic pains during wet weather; but to-day we do not consider insanity the result of the moon's influence, thus differing from our forefathers. During the middle ages it was considered quite as important to know the different constellations, the changes of the moon, the assumed course of the sun, and the influence of one planet on another, as to know the principles of anatomy, materia medicine, and botany; for in diagnosing a disease the place of birth, the hour, day, month and year of a man's birth were carefully considered; this gave a clue to the constellation under which a man was born, and a guide to the form of disease he might be expected to suffer from.

Astronomy has furnished a number of common medical terms, such as "Lunacy", which was believed to be due to the influence of Luna, the moon; the term "Cancer" was derived from the constellation of Cancer, the crab; sunstroke, which might or might

not be due to the sun's rays; a saturnine disposition was believed to be due to the influence of the planet Saturn; a mercurial disposition, to the planet Mercury; and a jovial disposition to the planet Jove, otherwise called Jupiter; but while these terms remain, the belief in their influence has died out.

About 400 years ago one of the most celebrated physicians in Europe, named Paracelsus, ordered the books on medicine written by Galen to be burned; as earlier writers assumed that disease was due to spirits, rather than, as he supposed, to the sun, moon and stars; but to-day Paracelsus's views on the origin of disease and treatment are looked upon as crude, amusing and surprising.

For instance one of his favourite remedies was dried and powdered mummy, of which he specifies six varieties; the Egyptian, Libyan and Arabian mummies were valuable, but the fifth kind were especially powerful and worth their weight in gold, as these were the bodies of men who had been hanged; therefore he says, "from such there is a gentle siccation that expurgeth the watery humour without destroying the oyle and spirituall which is cherished by the heavanly luminaries and strengthened continually by the affluence and appulses of the celestial spirits; whence it may properly be called by the name of constellated or celestial mummie".

A prescription written by Paracelsus may be interesting and instructive, as follows: Take of the moss growing on the head of a thief who has been hanged and left in the air; of powdered mummy, and of warm human blood 1 oz. each; of linseed oil, turpentine and Armenian bole, 2 drams of each; human suet, 2 oz. Mix thoroughly in a mortar and keep in an oblong urn.

It was believed that if this ointment was applied to a swelling when the moon was full, that the swelling would decrease as the moon waned; this might easily happen as Armenian bole is an astringent earth that would help reduce the swelling. As late as 1743 an Englishman referred to the value of moss (mould) from the head of a thief that was hanged and left to decay in the air by saying, "The vital spirits of a man to be strangled (by reason of the presence of his unhappy chance) do retire to the head and brains, and the violent constriction hindereth their going back to their principles; they remain there, and mingle with and are confounded with the spirits and balsam of the head and brains; and

though all animal functions do cease, nevertheless there remains a certain heat or warmness in the bones, nerves and similar parts. Now after this mixture, and through the help of this heat and the joint working of a heavenly influence, moss like a vegetable growing upon the skull of a man being hanged must needs be of a greater force than such as grows upon the head of another who dyed of some disease". To-day we smile at the faith men had in this ointment, and the wonderful cures that followed its use; and yet to-day we have thousands of persons who claim they were healed by faith in its various forms; faith healers, magnetic healers, charms of various kinds; religious relics as at Ste. Anne de Beaupre, etc.

The following prescriptions were used in Britain less than 200 years ago.

For Fever or Surfeits.

Prepared crab's eyes; red coral; white amber (finely powdered); and burnt hartshorn, of each, ½ oz.; oriental bezoar, 1 oz.; black tips of crab's claws (powdered), 4 oz.; grind on a marble stone and make into balls with jelly made of English viper's skin. Dose: one ball daily during the first quarter of the new moon.

For Consumption (Tuberculosis).

Snail shells, 1 peck—place near a fire until they stop hissing and spitting; then dry and grind in a mortar. Earth worms, 1 quart, slit and clean with salt and water,—beat them with the snail shells; then take angelica, celendine, wood sorrel, agrimony, bears-foot, barberry bark, great dock root, of each two handsfull; rue, ½ handful; rosemary flowers 1 quart; hartshorn, 1 lb.; turmerick and foenigreek, of each, 2 oz.; powdered saffron, ½ oz.; fresh cloves, 3 oz.; shred these ingredients and infuse in 3 gallons of strong ale for 12 hours. Dose: three spoonsfull in a glass of sack or white wine before meals. Commencing when the moon was full was believed to help matters.

For Infantile Convulsions.

Take 12 live moles, bleed, and when dead dry in an earthen vessel until they can be powdered; sift the powder through a fine

sieve, and give the child what would lie on a half-crown for three nights before the full and new moon.

For Consumption.

Take 12 doz. small griggs, wipe them clean, bake in a glazed pan until they are dry; powder and take what will lie on a half-crown, in a glass of old malaga or canary; take when the stars disappear in the morning.

It is a curious fact that in the play Macbeth, Act 4, scene 1, where the three witches are brewing a mixture in a cauldron, out of 22 ingredients mentioned by Shakespeare, 16 were in common use at that time as medicines, mummy being a favourite medicine for various diseases, being one of the ingredients along with 19 from the animal kingdom and only two from the vegetable kingdom, viz., "root of hemlock digged in the dark; and slips of yew, slivered in the moons eclipse", thus showing that Shakespeare was familiar with the medical opinions and practises of that day. The ancients had their medical gods, one of which was named Aesculapius, who was accused of bringing to life the dead; and at the request of Pluto he was killed by a thunderbolt sent by Jupiter. After his death he received divine honours, and, according to Servius, was placed in the sky and formed the constellation of Serpentarius one of the 48 constellations known to the ancients.

Now while we smile at the fantastic ideas of our joint forefathers, is it not possible for physicians to lose sight of the tremendous beneficial influence exerted by the sun in purifying our air and water; in furnishing light and heat; in stimulating animal and vegetable growth and without which disease and death would destroy all traces of animal and vegetable growth.

Toronto, Ont.

A SIMPLE INSTRUMENT FOR PROJECTING THE SOLAR DISC

By A. F. Miller

A non-achromatic telescope for direct visual observation is generally rather an abomination, though there are uses to which it has been, and may still be, usefully applied. However I have found by experience that if constructed for the definite observation of the sun by projection it will give results quite comparable with those to be obtained by the use in a similar way of a very much more costly telescope.

The first essential is, to use a lens of fairly long focal length and relatively small aperture. Such a lens may be obtained from any good optician for a trifling sum, being simply a spectacle lens of about 45 inches focus, finished to a circular shape instead of the usual ellipse; when so made it will have a diameter of about 1¼ to 1½ inches. This lens is to be mounted like a telescope objective in one end of a tube about 40 inches in length. The tube may be of any material or manner of construction found most convenient by the maker (as tin, wood, or rolled paper); but I suggest the employment of two or three of the tube-like cases of carton used for mailing calendars and pictures. Two of these put together by a slightly larger one forming the central portion and overlapping the others, form a tube extremely light, wonderfully rigid for the quantity of material, practically quite straight, and inexpensive. It being of great importance that the lens shall be centrally placed in the tube and square to the optical axis I suggest to the would-be constructor to mount it in a short piece of brass tubing having a shoulder turned square to fit the ground edge of the glass, the latter being secured in place by a ring of flattened spring-brass wire or in any other convenient way. If the amateur workman have not facilities to construct such a mounting the optician would probably furnish it along with the lens for a small additional charge, or a tube of stiff smooth paper might be substituted, but the brass tube would be best. I may say here that

the inside of the tube and the lens mounting should be coated with dead black, for which shoe-polish thinned with ink and applied with a swab of batting attached to a stick is quite suitable. A diaphragm formed of a ring of card fitting the inside of the tube and pierced with a central aperture ¾-inch in diameter should be placed in the body twelve inches from the extremity opposite to the object glass. For focussing, a tube about ¾-inch aperture and eight inches in length will be required. If the best results are to be obtained this focussing tube should be a piece of smooth thin brass tubing, such as may often be secured from a maker of electric-light or gas fittings; or it may be that a short draw-tube from a small telescope is available. If neither of these can be readily had, the focussing tube may be constructed from a sheet of stiff white paper rolled round a ruler and secured at the first and last wrappings with a little thin glue, the intermediate layers being better without any adhesive application. If such a draw tube be made, care must be taken to have it quite straight and of uniform external diameter. The focussing tube whether of brass or paper is to work in a *cloth draw*, that is, a band of smooth fairly thick woollen cloth encircling the draw tube once, tight enough to hold it steady but not so tight as to prevent smooth focussing. The ends of the cloth band are not lapped but sewed together with a few stitches. An "eye-end" may then be built round the cloth ring and draw-tube by wrapping round them a band of paper-strip till large enough to fill the end of the body-tube wherein it may then be secured with glue. If the maker has access to a lathe, a wooden end may be turned, having a central aperture in which the cloth ring may be glued. The projector may be a plano-convex lens of about 1½ inches focal length, the essential point being that its diameter should be greater than the solar image formed in the principal focus of the objective, which image in the case I have stipulated will measure about 9.8 mm. or .393 in. A better projector would be the pair of lenses forming the ocular in the erecting eye-piece of any small pocket telescope, or the low power ocular of a small microscope would give a good result. Needless to say the draw tube and eye-end should be blackened inside.

The complete instrument is intended for use at an open window or similar place, the image formed by the objective and magnified by the secondary lens or ocular being projected on a sheet of card placed behind at a distance where the magnified solar image will have a diameter of seven inches or so. This card screen may be conveniently held in place by two thin strips of flexible wood fixed to the body by wire rings and opened out to take the screen between them, its edges going into notches cut in the strips. In practice I have found no difficulty in holding the projector steady by resting it against the window sash or side of the window-frame. If desired, it might be mounted between two laths nailed top and bottom to small blocks provided with pointed nails arranged to fit holes made to take them in the bottom of the raised sash and the window-casing below. The window blind should be drawn down and the rest of the window darkened so far as may be convenient by drawing the curtains together, or attaching below the blind a sheet of thick paper with an aperture through which the body of the projector is passed. It is not essential to make the room quite dark, only necessary that the projected disc shall be in strong shadow. Should outstanding colour prove objectionable the aperture of the objective may be reduced by an external diaphragm.

With a projector of the kind described, all the principal facts relative to the sun may be readily demonstrated and shown to several persons at once. Due attention being given to focus and appropriate size of the projected disc, sun spots with their umbræ and penumbræ will be clearly seen whenever spots exist on the sun's surface, the foreshortening of the groups near the limb and their spreading out as they advance towards the central line being an obvious fact. The faculæ lying around the spots will be detected as well as those often occurring near the solar limbs. The darkening of these latter regions as compared with the central part comes out distinctly, proving the existence of an absorbing layer surrounding the great luminary. The mottling of the sun's surface may often be distinguished. The solar rotation may be clearly demonstrated and its period approximated by continuous regular observations. With a sheet of paper ruled in small squares we soon arrive at some idea of the vast dimensions frequently

attained by sun-spots. The varying apparent diameter of the sun at mid-winter and midsummer may be proved by circles drawn to coincide with the projected images at those seasons. At the times of solar eclipses observations of special interest and even of utility may be made. These and other facts which will suggest themselves to the user all come within the scope of the very simple and inexpensive apparatus I have described. Of course fine details are never seen as well by projection even with a fine refractor as by visual observation; but speaking from experience, I can say that the imgaes projected with the instrument of which I have spoken do not fall very far short of those similarly yielded by a good achromatic of three inches aperture.

Toronto, Ont.

MEETINGS OF THE SOCIETY

AT TORONTO

March 29.—The Society met in the Physics' Building of the University at 8 p.m. As the President, owing to illness, was unable to be present the Vice-President, Mr. W. E. W. Jackson, occupied the chair.

The following were elected Members of the Society:

William Gore, Room 625, Confederation Life Bldg., Toronto.

M. B. Tucker, B.A., B.D., Brighton, Ont.

Philip S. A. Morton, 86 Asquith Ave., Toronto.

H. O. Skinner, 651 Yonge St., Toronto.

The Paper for the evening was given by J. A. Pearce, on the subject "Magnetic Observations in the Field." The object of a Magnetic Survey is to find the values of the secular changes in the magnetic elements by comparing the observations taken at different locations with those of an earlier epoch.

To fully determine a force it is necessary to know its point of application, its direction and its magnitude. The magnetician must therefore take astronomical observations for latitude and longitude,—in order to determine his geographical co-ordinates,—and magnetic observations for declination and inclination,—to establish the direction of the resultant of the earth's magnetic force at the point of observation; and finally, he must measure the horizontal intensity from which the value of that total intensity is derived.

The speaker described the instruments used upon a survey, and explained the method of conducting the observations. The station at Mattawa, Ontario was taken as an example and the recorded observations and computations shown by slides. A sketch of the station was shown, illustrating the manner in which the exact positions defined in order that a future observer may easily locate it.

On comparing the 1920 values of the elements determined at 10 stations in Ontario with the 1910 values, it was readily seen that the western declination is increasing at a rate of about 4′ annuallly, the dip is also increasing, at a rate of 0′.3; and the horizontal intensity is decreasing by 30 gausses annually.

The lecture was illustrated by some three dozen slides showing many of the stations occupied in Ontario, and various places of the work.

April 12.—The Society met in the Physics' Building of the University, the Vice-President in the chair.

Miss M. H. Anderson, 26 Glenlake Ave., Toronto, was elected a member.

The paper for the evening was given by Mr. Noel Ogilvie, D.L.S., Superintendent of the Geodetic Survey of Canada, on the work of the Survey. The paper is printed in this issue.

The paper was illustrated by many lantern slides, and after its presentation a lively discussion followed. Hearty thanks were tendered Mr. Ogilvie.

April 26.—The Society met in the Physics' Buildings of the University at 8 p.m., the Vice-President in the chair.

Mr. H. R. Bristow, 871 Third St., Medicine Hat, Alberta, was elected a Member.

Prof. C. A. Chant exhibited a model of the orbits of the earth and Winnecke's Comet which is due to arrive at perihelion on or about June 15th of this year. He explained the importance attached to this return of the comet, and showed a slide which he had received only that morning from Prof. Barnard of the Yerkes' Observatory, and which was made from the original negative taken by Prof. Barnard on April 10th. It showed the comet, a faint hazy spot, of magnitude twelve.

Mr. John A. Paterson, K.C., who was to have given the paper of the evening on "Percival Lowell, his life and work," through illness was unable to be present. In his place Prof. S. Beatty of the Department of Mathematics of the University, gave a lecture upon "The Notion of Infinity in Mathematics."

Because in the natural world we have to deal with finite quantities, one might think that the idea of infinity is quite beyond our reach. We seldom use numbers descriptive of anything, having more than 8 or 9, or at the most 12, figures in them. Although we can create large numbers by writing down a series of figures we are able to understand their significance. It would be a very large number, but there would be only a finite number of drops of water in the ocean.

We conceive the notion of infinity when we begin to think of numbers, not as denoting things in the physical world, but as exisiting in the world of thought. The first type of infinity is found in the conception of "successor". Suppose you think of the series of numbers 1, 2, 3, 4, 5, etc., and leave orders that each number is to have a successor; you are forced to conclude that there is no end to the series, that is—the series is infinite. Another notion of infinity is that involved in the consideration of all the proper fractions from 0 to 1. The lecturer also showed that there is an infinite number of incommensurable numbers. He next discussed some properties of finite and infinite sets, and concluded with an explanation of the Petersburg Game.

May 10.—The Society met in the Physics Building of the University at 8 p.m., the President, Mr. J. R. Collins in the chair.

Mr. W. F. H. Waterfield, Scutchamore Ranch, Nakusp., B.C., was elected a member.

Dr. J. S. Plaskett, Director of the Dominion Astrophysical Observatory, Victoria, B.C., gave the address of the evening, on the work of that observatory. He had first conceived the idea of a large reflecting telescope for Canada in 1910, while attending a conference of astronomers in Pasadena, California; and on his return to Ottawa urged its construction. The observatory was decided upon by the Government in 1913, and finally completed on Saanach Hill, Victoria, B.C., in 1918. The lecturer showed a number of good lantern slides of the buildings and the 72-inch reflector within its dome.

The telescope is chiefly used to measure the radial velocities of stars. The programme of work included some 700 stars, in that portion of the sky within

the range of the instrument. In less than three years the staff has completed the measurement of 520 stars, 150 of them being binary systems. Generally six photographic plates of the spectrum of each star are obtained, the spectrum of the iron arc being used for comparison. Dr. Plaskett gave a very lucid account of the observatory and its work, illustrating his address with numerous lantern slides.

May 25.—The Society met at 8 p.m. in the Physics Building of the University of Toronto, the President, Mr. J. R. Collins, in the chair.

Mr. W. E. McMullen, Dep't of Lands and Mines, Fredericton, N.B., and John Patterson, M.A., F.R.S.C., Toronto, were elected members.

The series of recent auroras received some attention. A. F. Hunter had observed a northerly display at Barrie, at 1 a.m. on May 8th, and besides the general display at Toronto on the evening of May 13th, reported that at 3.30 a.m. on May 16th the auroral streamers were in a dancing, pulsating condition, which continued until daylight. The displays coincided with the appearance and development of a large group of spots on the sun.

Mr. A. F. Miller, who had observed the aurora on the 13th and had examined its spectrum, had noticed that the aurora is always more pronounced when the sunspots are in a state of activity, and there had been great activity in the recent group of spots.

Prof. Chant mentioned the occurrence of the aurora a day or two after the spot had been central on the sun, which gave time for the discharge of electrified particles to reach the earth.

Miss Buckley had observed changes in the recent sunspots with the naked eye, the group being large enough to be thus seen.

Dr. J. B. Fraser read a paper on "The Influence of Astronomy on Medical Science", chiefly during the last 200 years. Astronomy has given many words to the language, as—lunacy, jovial, saturnine, etc. The essayist cited the views of Paracelsus who lived 400 years ago, and described some of the grotesque cures of the early times.

Dr. A. D. Watson spoke of the influence of the sun on disease, and thought if people could live more in the sunlight they would be benefited.

A. R. Hassard, B.C.L., read a paper on "The Influence of Astronomy on Agriculture", referring to the mythical influence of the moon, the relationship between sunspots and temperature, cold weather after an aurora, etc., all of which had some influence on the growth of crops. Rainmaking in the North-west, and other features were dealt with in this interesting paper.

Mr. A. F. Miller exhibited a telescopic apparatus for projecting the image of the sun, and gave a description of its construction and use.

J. A. Pearce, *Recorder.*

AT OTTAWA

February 11.—C. C. Smith, B.A., D.L.S., gave the lecture of the evening on "The Size of the Stars."

The lecturer outlined the method employed by Prof. Michelson to measure the diameter of the giant star, Betelgeuse. The problem simply stated was similar to the measurement of the diameter of an old one cent piece placed 70 miles away, with some one shaking the coin.

Astronomers for years have endeavored to find some way of direct measurement of the size of stars, but all results so far were based on some assumption. Eddington of Cambridge and Russell of Princeton determined theoretical diameters of a number of stars and it was their hope that in the near future some direct method would be developed to confirm their results. Professor Michelson solved the problem by applying the principle of interference, as he had suggested 30 years previously. As the method used has already been described in the JOURNAL it is not necessary to explain it here.

Professor Michelson's invention is of the greatest value, not only in that it reveals the size of stars, directly and accurately, but also in that it affords a check on modern theories of the evolution of stars, of their temperatures, their densities and masses. It is of interest to know that the theoretical results of Eddington and Russell were in good agreement with Professor Michelson's results.

Dr. R. E. DeLury presided at the meeting.

February 25.—Dr. F. C. Henroteau gave the lecture of the evening on "The Size of the Universe."

Dr. Henroteau in his opening remarks referred to the astronomical work carried on by the various governments throughout the world; Canada and Argentina were well in the lead. By means of the large telescopes at the disposal of astronomers throughout the world data had been collected in the last few years to give some idea of the dimensions of the Universe, and that our earth, apparently large, when compared with the universe, drops into absolute insignificance.

The lecture was well illustrated by lantern slides, showing pictures of star fields and nebulae. The light of the sun, which is 93,000,000 miles from the earth, takes 8.3 minutes to reach us, travelling at a speed of 186,300 miles per second. The light from the nearest star travelling at same speed takes 4.4 years to reach us. Our stellar universe, it is believed, has between 1,000,000,000 and 2,000,000,000 stars of all sizes comparable to our sun, which, itself, is 1,000,000 times as large as the earth. It was shown by certain lines of reasoning that our universe is so large that light would take about 30,000 years to cross it. It was stated that the thousands of other universes, each with its myriads of stars, appear to us in shape of spiral nebulae. The light of the Andromeda nebula, another universe of stars, takes 650,000 years to reach us and the light of the farthest universe is reckoned to take about 50,000,000 years to come to us.

In conclusion, the lecturer stated that it is some consolation that on this tiny earth man had developed to contemplate and fathom these immensities.

Mr. Albert Hawkins, D.L.S., Vice-President, occupied the chair.

May 8.—Dr. Lachlan Gilchrist, of the University of Toronto, gave the evening lecture, his subject being, "Atoms, and their Messages from the Stars".

The lecturer first outlined the discovery of the X-rays and the Zeeman effect in 1895, and the consequent impetus to the study of the atom. Hale and others applied the Zeeman effect to the study of sun-spots and demonstrated the existence in them of magnetic fields. Roentgen's investigations into his X-rays led to the discovery of polonium, thorium and actinium and applications of radio-active phenomena were made to physics, chemistry, geology and medicine. Wehnelt found that electrons could be more easily obtained from a hot body than from a cold one and this led to developments in long distance telephony and in the wireless telegraph; and also to the Coolidge hot-cathode tube. The property of hot bodies to emit electrons suggested that during auroral displays, in the upper atmosphere the electrical conditions were influenced by the emission of electrons from the sun.

In 1912 by using cleavage planes of a crystal the spectrum of the X-rays was obtained. A line spectrum was secured showing three series of lines, the K, L, M series, whose wave-lengths were characteristic of the metal of which the target was made.

The lecturer referred to the work of Kelvin, Thomson, Rutherford, Rayleigh, Planck and Bohr, which led to the belief that the hydrogen atom consists of a single positive nucleus with a negative electron revolving about it in a circular orbit, the helium atom two units of positive charge and two electrons, and so on for other elements. The dimensions of the electron and atom as determined by Rutherford were compared with the dimension of the solar system—one excessively minute, the other excessively large.

The lecture was well illustrated by experiments and slides.

Dr. R. E. DeLury, President, occupied the chair.

April 1.—R. A. A. Johnston, F.R.S.C., gave the lecture of the evening on "Visitors and Captives from outer Space".

The lecture was particularly well illustrated by slides and numerous models and specimens of meteors. Mr. Johnston stated that the total number of meteors in museum collections totalled 650. It has been figured out that 20,000,000 meteorites come into the earth's atmosphere every 24 hours. There seems to be a relation between meteor showers, sun-spots and rain or snow. The analysis of snow and rain for nitrogen compounds seems to show that the nitrogen content follows very closely to the curve of meteor showers and sun-spots.

It is sometimes thought life was first brought to this earth by meteors. It is possible to conceive of the destruction of life, as it exists, on this planet by showers of certain kinds of meteors, which would use up the air content which is essential to man's existence. Meteors have been known to destroy life by coming in direct contact.

There are two kinds of meteors,—progressive and retrograde. Their velocity is from 15 to 4 miles per second. On entering our atmosphere, sometimes they are torn to pieces and their thin surface layer is heated to incandescence due to the resistance of the earth's atmosphere. Meteors vary in weight from a few pounds to many tons. Peary's Meteor brought from Greenland weighs 37 tons. The meteorite crater in Arizona, if theory is correct, gave evidence of a meteor

which would exceed this meteor many times. Meteors in their passage over the earth make a terrific noise, almost like thunder. In 1820 an immense meteor passed over Europe. The lecturer spoke of one which passed over Ontario in 1886, which he both heard and saw, sounded like cannonading as it sped on its way. In 1904 a meteor was found at Shelburne, Ontario, the day after it had fallen, a few feet from the house whose occupants it had greatly alarmed the previous evening by its thundering noise. Meteors outside of the very thin surface layer about 1/10 of an inch are exceedingly cold, thought to have the temperature of space.

Dr. R. E. DeLury, president, occupied the chair.

April 15.—Mr. G. H. Herriot, B.A.Sc., D.L.S., gave the lecture of the evening on "Refraction, or the Bending of Light".

The lecturer dealt with the theory, index of refraction, critical angle, and some effects of atmposheric refraction as well as the practical application of refraction in the ordinary telescope, spectroscope, magnifying or reducing lenses and the ordinary eyeglass. The lecture was well illustrated by slides and experiments.

Light travelling from one medium to another of different density, bends at the surface of the medium it is entering. The bending of light increases the altitude of heavenly bodies. The sun rises about two minutes earljer and set about two minutes later on account of refraction. Mirages are due to the different densities of the atmosphere, causing the rays of light to bend. The sun and moon, when rising or setting, has a flattened ott appearance, caused by refraction. Refraction also causes twinkling of the stars. The same principle makes the moon, even in time of total eclipse, visible, and also lengthens twilight.

The crystalline lens of the human eye was an example of refraction, as the light passed from a medium of one density to one of another density. The magnifying and reducing lenses and also the eye glass were all examples of refraction as they depended on this principle. The same idea was made use of in the telescope and in the spectroscope which had a prism, a set of lenses and a telescope to view by. The spectroscope was extensively used in astronomical, and pathological research. By means of a prism in front of a projection lantern, the lecturer showed how a ray of light is broken up into its primary colours.

The effects of refraction in the human eye, in lenses, in prisms and in the combinations of lenses and prisms were discussed and illustrated.

Dr. R. E. DeLury, president, occupied the chair.

R. J. McDiarmid,
Secretary.

AT MONTREAL

May 26.—The President, H. E. S. Asbury, occupied the chair. The attendance was between 125 and 150.

The following were elected members of the Society:

John G. MacKinnon, Industrial Dept., Y.M.C.A., 144 Hadley St., Montreal.
John L. Clarke, Engineering Dept., Bell Telephone Co., Montreal.
Wm. P. McFeat, Patent Attorney, 815 Power Bldg., Montreal.
Mrs. H. E. Wade, 545 Madison Ave., Montreal.

After remarking that the next meeting of the Society would not be held until September, the President called upon Miss M. Ellicott, one of our earliest and our first lady member, to read her paper on "Lessons from the Stars". This paper was of considerable literary merit, and was full of beautiful thoughts on high ideals to be brought into our every-day life, and which could be inculcated by observation and study of the serene grandeur of the heavens. Charming poetic quotations were interwoven throughout the paper.

The President then introduced Dr. J. S. Plaskett, of the Dominion Astrophysical Observatory at Victoria, B.C., who addressed us on "Modern Ideas of the Universe". Dr. Plaskett first very briefly reviewed the early ideas of the Egyptians and Greeks, mostly confined to the earth, sun and moon. It was then supposed that the sun having travelled across the sky from east to west, returned by some subterranean passage, ready for the next day's journey. The Greeks thought the earth was supported on 12 columns, while the Egyptians thought it was held up by four elephants, standing on an enormous tortoise, floating on a sea, presumably unsupported. The change in ideas brought about by the discoveries of Copernicus and others was referred to, but the stellar universe was considered subsidiary to the solar system until the discoveries of Sir Wm. Herschel. Sir Wm. Herschel advanced the theory of a stellar universe shaped something like a grindstone, which theory is to a considerable extent corroborated by modern research. The lecture was illustrated with some exceptionally fine lantern views, most of which were taken with the aid of the 72-inch telescope at Victoria.

About ten or fifteen years ago, the dimensions of the stellar universe were estimated as about two to three thousand light years in depth, by seven to ten thousand light years in diameter; but within the last two ot three years these dimensions have been magnified about twenty times. Some splendid views of the Milky Way were shown, and the lecturer stated that the apparently dark spots were now supposed to be due to opaque, nebulous matter, and not to the complete absence of stars. Views of various types of nebulae were shown, and theories given upon their formations. The spiral nebulae described by some as "island universes" were shown. The nearest cluster is distant over twenty thousand light years, and some are as distant as perhaps two hundred thousand light years.

Prof. A. S. Eve, in moving a vote of thanks to the lecturer, told something of the work done by Dr. Plaskett in the observatory at Victoria, and recalled that in this same room where Dr. Plaskett had spoken of such vast distances, Prof. Rutherford had done such splendid work in his studies of the atom. Prof. Eve commented on the indifference of the unthinking multitude who thronged the moving picture places, but neglected lectures such as this. The vote of thanks was seconded by Prof. L. V. King.

The meeting concluded with the singing of the National Anthem.

H. E. MARKHAM, *Recorder.*

NOTES FROM THE METEOROLOGICAL SERVICE

APRIL, 1921

TEMPERATURE

The temperature was from 2 to 4 degrees below the average in British Columbia and from average to 3 degrees below in the Western Provinces, elsewhere in the Dominion it was above the average, the positive departure varying from 5 to 9 degrees in Ontario and from 1 to 5 degrees in Quebec and the Maritime Provinces.

TEMPERATURES FOR MONTH OF APRIL, 1921

STATIONS	APRIL Highest	Lowest
Yukon		
Dawson	54	− 6
British Columbia		
Atlin	—	—
Agassiz	72	28
Barkerville	51	9
Kamloops	75	22
New Westminster	73	32
Prince Rupert	64	32
Vancouver	66	30
Victoria	66	32
West Provinces		
Battleford	60	5
Calgary	70	16
Edmonton	64	19
Medicine Hat	69	7
Minnedosa	68	16
Moosejaw	69	14
Oakbank	67	15
Portage la Prairie	75	15
Prince Albert	59	4
Qu'Appelle	69	10
Regina	70	6
Saskatoon	64	5
Souris	71	8
Swift Current	68	14
Winnipeg	70	16
Ontario		
Agincourt	76	24
Oak Ridges	77	20
Bancroft	81	10
Barrie	77	20
Beatrice	81	14
Bloomfield	75	22
Chapleau	—	—
Chatham	86	23
Clinton	79	11
Collingwood	83	20
Cottam	78	22
Georgetown	80	21
Gravenhurst	85	17
Grimsby	82	26
Guelph	78	21
Haliburton	85	14

STATIONS	APRIL Highest	Lowest
Ontario—cont.		
Huntsville	79	13
Kenora	64	11
Kingston	74	23
Kitchener	81	21
London	80	21
Lucknow	82	17
North Gower	75	22
Oshawa	64	25
Ottawa	80	18
Paris	84	23
Parry Sound	83	14
Peterborough	80	20
Port Arthur	66	14
Port Burwell	79	25
Port Dover	75	24
Port Stanley	—	—
Queensborough	76	18
Ronville	78	14
Southampton	82	19
Stonecliffe	82	10
Stoney Creek	78	27
Toronto	75	26
Uxbridge	78	15
Wallaceburg	82	31
Welland	82	22
White River	75	−9
Quebec		
Brome	77	23
Father Point	66	8
Montreal	75	23
Quebec	80	20
Sherbrooke	78	21
Maritime Provinces		
Charlottetown	74	16
Chatham	80	8
Fredericton	83	14
Halifax	72	18
Moncton	79	7
St. John	75	20
Sussex	81	7
Sydney	70	18
Yarmouth	72	30

Precipitation

The precipitation in British Columbia was a little below the average in some districts and a little above in others. In the Western Provinces it was in nearly all localities much more than the normal quantity, a number of places recording more than double the average amount. In Ontario, except in a few isolated places, it was above the average and to a marked extent over the southern portion of the province. In Quebec, except quite locally, there was rather less than usual. In New Brunswick and Prince Edward Island there was a small excess in most places, whereas in Nova Scotia there was a deficit of from one to nearly two inches.

SEISMOLOGICAL NOTES

Toronto and Victoria each recorded nine earthquakes during the month. The largest, with a trace-amplitude of 4.5 mm. at Victoria, and 2.8 mm. at Toronto, occurred on the 10th. This quake was felt in the North end of Queen Charlotte Island. Two other quakes on the 3rd and 12th with smaller amplitude were possibly centred off the coast of the same island.

J. Y.

Magnetic Disturbances—March, 1921

During the month of March the magnetic forces were for the most part quite normal. A moderate disturbance was recorded on the 15th at both Agincourt and Meanook; the amplitude at Agincourt was in H 122 γ, in Z 97 γ and in D 35′.2 and at Meanook in D 1° 53′.1.

Sunspots were quite small and few in numbers throughout the month. On the 8th the sun's visible surface was entirely free of spots.

Auroral displays were also quite infrequent and the few observed were of a low order. They were more generally observed on the 9th, 14th, 15th and 28th. W. E. W. J.

MAGNETIC OBSERVATIONS

By W. E. W. Jackson

The accompanying tables give a summary of the results obtained at Agincourt and Meanook magnetic observatories for the year 1920.

The values of D, H and Z for Agincourt, and D for Meanook are obtained from the hour-readings of the photographic records. The value of I at Agincourt is deduced from the H and Z means. The H and I values for Meanook are obtained from absolute observations, uncorrected for diurnal variation, made twice a month for H and weekly for I. The value of Z is deduced from the means of H and I. All observations are corrected to International Magnetic Standard.

RESULTS OF MAGNETIC OBSERVATIONS AT AGINCOURT FOR 1920
LAT. 43° 47′ N.; LONG. 79° 16′ W.

West Declination

Month	Mean of Month	Maximum	Date of Max.	Minimum	Date of Min.	Monthly Range	Mean Daily Range From 24 hour readings	Mean Daily Range From means of Extremes
	° ′	° ′		° ′		° ′	′	′
Jan.	6 43.4	6 59.2	10	6 27.6	23	0 31.6	8.6	15.1
Feb.	43.7	7 08.0	24	6 24.2	17	0 43.8	9.4	14.8
Mar.	44.8	8 44.9	22	4 57.2	4	3 47.7	11.2	33.6
Apr.	44.5	7 20.2	15	6 09.1	15	1 11.1	11.9	24.9
May	44.7	7 08.6	13	6 22.3	13	0 46.3	12.9	20.4
June	44.1	6 58.5	11	6 22.2	10	0 36.3	13.5	19.0
July	45.1	7 07.0	15	6 12.8	6	0 54.2	14.2	20.6
Aug.	46.3	7 13.7	4	5 55.9	21	1 17.8	13.9	23.1
Sept.	46.9	7 44.6	29	5 47.6	28	1 57.0	11.9	28.1
Oct.	47.1	7 34.3	10	6 20.1	27	1 14.2	9.2	20.8
Nov.	47.2	7 04.7	7	6 14.0	26	0 50.7	8.7	16.0
Dec.	47.5	7 17.9	26	6 06.7	4	1 11.2	6.5	15.9

RESULTS OF MAGNETIC OBSERVATIONS AT AGINCOURT FOR 1920
LAT. 43° 47′ N; LONG 79° 16′ W.

Horizontal Force

Month	Mean of Month	Maximum	Date of Max.	Maximum	Date of Min.	Monthly Range	Mean Daily Range From 24 home readings	Mean Daily Range From means of Extremes
	γ	γ		γ		γ	γ	γ
Jan.	15884	15920	20	15822	17	98	35	53
Feb.	81	15918	24	764	16	154	31	52
Mar.	58	16310	22	118	22	1192	70	159
Apr.	64	16018	17	564	15	454	50	106
May	76	15984	28	599	1	385	49	94
June	77	15989	10	737	10	252	43	70
July	72	15993	15	783	8	210	46	77
Aug.	67	16154	12	730	21	424	48	82
Sept.	49	16220	28	394	29	826	58	146
Oct.	46	15892	23	473	10	419	42	80
Nov.	51	15893	26	753	6	140	29	55
Dec.	56	15905	5	715	26	190	28	56

Vertical Force

Month	Mean of Month	Maximum	Date of Max.	Minimum	Date of Min.	Monthly Range	Mean Daily Range From 24 home readings	Mean Daily Range From means of Extremes
	γ	γ		γ		γ	γ	γ
Jan.	58230	58253	11	58200	10	53	7	31
Feb.	58224	58281	24	58184	16	97	9	19
Mar.	58221	58754	22	57685	22	1069	22	107
Apr.	58202	58402	17	57988	30	414	25	67
May	58179	58276	13	58030	1	246	18	50
June	58164	58260	10	58087	10	173	14	33
July	58146	58244	15	58039	8	205	16	36
Aug.	58139	58426	12	58052	21	374	17	52
Sept.	58129	58516	28	57944	29	572	37	100
Oct.	58122	58174	23	57945	10	229	15	34
Nov.	58115	58312	26	58044	6	268	12	29
Dec.	58122	58209	4	58022	26	187	10	22

RESULTS OF MAGNETIC OBSERVATIONS AT MEANOOK FOR 1920
LAT. 54° 37′N.; LONG. 113° 21′W.

DECLINATION EAST

Month	Mean of Month	Maximum	Date of Max.	Minimum	Date of Min.	Monthly Range	Mean Daily Range From 24 hourly readings	Mean Daily Range From means of Extremes
	° ′	° ′		° ′		° ′	′	′
Jan.	27 39.9	28 17.0	30	26 39.7	10	1 37.3	6.8	24.1
Feb.	39.6	29 40.1	16	26 50.7	26	2 49.4	6.4	28.3
Mar.	40.0	30 31.4	22	25 23.9	5	5 07.5	11.9	69.6
Apr.	38.0	29 37.8	15	25 47.9	15	3 49.9	17.8	50.9
May	39.0	29 31.4	1	26 33.1	3	2 58.3	16.2	44.1
June	38.0	28 54.7	10	26 58.2	6	1 56.5	17.1	28.8
July	38.3	28 55.2	23	26 35.9	23	2 19.3	17.3	30.6
Aug.	38.1	28 32.4	30	26 39.8	8	1 52.6	17.6	38.9
Sept.	38.7	29 08.2	29	26 10.8	8	2 57.4	12.6	60.0
Oct.	38.7	29 34.7	10	26 22.4	10	3 12.3	11.3	43.0
Nov.	37.7	28 50.4	4	26 45.4	5	2 05.0	8.8	30.5
Dec.	37.0	30 13.4	26	25 56.3	26	4 17.1	10.4	32.4

RESULTS OF MAGNETIC OBSERVATIONS AT AGINCOURT AND MEANOOK FOR 1920

Month	Ag. I	Me. I	Me. H	Me. Z
	° ′	° ′	γ	γ
Jan.	74 44.5	77 54.5	12934	60375
Feb.	44.4	53.5	19	219
Mar.	45.8	54.8	12	298
Apr.	45.2	54.2	08	228
May	44.2	53.2	08	142
June	43.9	52.9	40	266
July	43.9	52.8	15	141
Aug.	44.1	53.5	11	182
Sept.	44.9	53.9	20	258
Oct.	45.0	53.6	26	260
Nov.	44.6	53.8	26	277
Dec.	44.5	53.0	28	218

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries

A VALUABLE WORK ON THE NEW STARS

Any one who attempts to investigate the nature and behaviour of the new stars, especially as presented by the spectroscope soon finds himself in a tangled maze of details; and as the discovery of these remarkable objects has been quite frequent during recent years, the task of systematically examining the records and making a comparative study of them has become a matter of great importance and urgency.

Hence it is gratifying to learn that the large amount of material which has been accumulated during the last twenty years at the Lick Observatory is to be critically discussed by Astronomer W. H. Wright who himself secured the major part of it.

In the first part of Volume 14 of the *Publications of the Lick Observatory* (26 pages) is an account of the spectrum of Nova Ophiuchi, which was discovered by photography at the Harvard Observatory by Miss Mackie and announced on October 22, 1919. Observations began at the Lick Observatory on October 30 and continued until November 22, when proximity to the sun prevented further work until the following spring.

The star at maximum brightness had a magnitude of 7.2 and so was not visible to the unaided eye at any time. The emission spectrum consisted of radiations of hydrogen and the enhanced lines of calcium, iron and some other unidentified ones. The dark line spectrum closely resembled that of Alpha Cygni. The star reached the "nebular" type in May, 1920.

DOINGS AT MOUNT WILSON

The Annual Report of the Director of the Mount Wilson Observatory for 1920 contains so much condensed information that it is hardly possible to compress it further. Perhaps the most interesting portion deals with the great 100-inch telescope—especially its being employed for measurements by Michelson's interference method. It was also used for photographing nebulae

and the moon, and for other purposes. Another project on hand is the measurement of the velocity of light with greater accuracy than hitherto attained. It will be done by a modification of Foucault's method, the second station being perhaps 16 miles away. Another striking research was made into a method of obtaining very high temperatures. By means of a powerful electrical discharge a fine wire was vapourized so rapidly that its intrinsic brightness was 100 times that of the solar surface, which would mean that the temperature was about 20,000 C. These are but a few of the matters described in the 57 pages of the report. Indeed one can hardly name any branch of astrophysical work which has not received a distinct contribution at Mount Wilson during the year.

It may be of interest to state here (though the information is not contained in the above report) that the diameter of Arcturus has lately been measured at Mount Wilson. The separation of the outer mirrors of the interferometer was 19 feet and the angle subtended by the star was deduced to be 0″.024. With a larallax of 0″.12 this gives a diameter of 19,000,000 miles.[7]

AUDIBILITY OF THE AURORA

Further evidence on this question is sent by Mr. W. E. Harper, of the Astrophysical Observatory, Victoria, B.C. He gives a portion of a letter from G. J. Burnett, of Victoria, describing the great display of August, 1916, as follows:

"The display covered the whole of the northern sky from S.W. to S.E. while overhead the arches and ribbons of light extended to the zenith, and the streamers and shafts of light extended several degrees past the zenith to the south. It was when the streamers darted to the zenith that I became conscious of sound. At first I thought it only my imagination, but the recurrence of the streamers with the sound itself was identical.

"The conviction came to me when watching the kaleidoscope character of a ribbon of light as if invisible hands were shaking it. Near the horizon the sound was apparent when not watching the streamer.

"The nature of the sound is possibly best described from the imagination, and I would describe it as the delicate swish of fine

snow as heard sometimes in a quiet room of a winter's night upon the window panes."

A VETERAN STUDENT OF THE MOON

A short time ago I had the pleasure of a visit to the home of Mr. H. B. Witton, of Hamilton, Ont., who for many years has been a student of the moon, and also of the Sanskrit language. Mr. Witton is now in his 90th year but he still retains an active interest in his favourite studies.

As early as 1881 Mr. Witton read before the Hamilton Scientific Association a paper on "Selenography", and it was in a report of this paper which appeared in a Toronto newspaper that I first saw that somewhat mysterious word, which a dictionary informed me meant the study of the surface of the moon. Mr. Witton prepared an excellent map of the moon about 30 inches in diameter. Quite recently he has been engaged upon an index to the various features of the moon. In it the names of the objects are given in alphabetical order, together with the size and position of each, the name of the person who bestowed the name upon the object and also biographical information regarding the one after whom the object was named. It is to be hoped that the Index will be completed and put in print, as it would certainly be of value in a study of the moon.

Among the treasures in Mr. Witton's fine library are Beer and Mädler's "Der Mond", published in 1837; and a fine tall copy Hevelius's "Selenographia" (Danzig, 1647), the earliest great work on the geography of the moon.

ASTRONOMY AND ASTRONOMERS

Under the title, "L'Astronomie et les Astronomes", a very useful work has recently been published by Auguste Collard, librarian at the Royal Observatory of Belgium (Brussels, G. van Oest, 1921, 120 pp.). It is a repertory of works on astronomy published since 1880, thus supplementing Houzeau and Lancaster's admirable "Bibliographie". There are eight divisions, as follows: Dictionaries and encyclopedias, Nos. 1 to 23; Biographies of astronomers, 24 to 52; Treatises on astronomy, 53 to 475; History

of astronomy, 476 to 558; Bibliographies of astronomy, 559 to 667; Atlases of astronomy, 668 to 697; Astronomical periodicals, 698 to 741; Astronomical tables, 745 to 758. At the end is an index to the names of authors and to anonymous works. In this the place of publication of this JOURNAL is stated to be Ottawa, instead of Toronto.

ONE HUNDRED GOOD SLIDES

The observatories do a great service to teachers of astronomy when they supply lantern slides from the negatives which are continually accumulating, and there has been recently published by the University of Chicago Press an admirable selection of one hundred slides made from negatives obtained at the Yerkes Observatory. These comprise photographs of solar phenomena, the moon, the planets, comets, stars and clusters, nebulae, the Milky Way, stellar spectra and buildings and instruments; and it is needless to say they are of the brightest quality. The present writer has used almost every one of them and can recommend them. A special price of $62.50 is made for the complete set.

DEATH OF MRS. BARNARD

The announcement of the death of Mrs. E. E. Barnard, which occurred at Williams Bay on May 25, was received with deep regret by a large circle of friends. Mrs. Barnard had not been in good health for some time, but her death was immediately due to at stroke of apoplexy. Simple services were held at the house on May 26 and interment took place at Nashville the next day. Sincere sympathy will be extended to Professor Barnard by his multitude of friends throughout the world. C. A. C.

ASTRONOMICAL NOTES

THE ECLIPSING VARIABLE U CEPHEI

(*Photometric Study of U Cephei* by R. S. Dugan. *Contribution* No. 5, Princeton University Observatory.)

The light variation of this star is very well defined by the 14,112 measures. Range of variation is 2.28 magnitudes at primary eclipse, which is total, and 0.09 magnitude at secondary.

U Cephei is of spectral type A0 with peculiarities at normal light, while the spectrum of the fainter component at time of total eclipse is K0. The brighter star type A intermediate between a giant and a dwarf is totally eclipsed by a star of greater diameter and smaller brightness, probably smaller mass, clearly in the giant stage as a K type star. The points of special interest which the light curve reveals are 1st, greater brightness of advancing side of brighter star; 2nd, reflection on darker star; 3rd, marked ellipticity of figure in the stars; 4th, asymmetry in the light curve, which was interpreted as a tidal lag in the ellipsoidal figure of the principal star. This last point, together with the available evidence that the period is 9 seconds longer than it was 60 years ago, indicates that tidal evolution is actually in progress. The observations indicate that the star discs are two or three times as bright at centre as at the limb.

R. J. M.

THE METRIC SYSTEM IN JAPAN

L'adoption obligatoire du Systeme mètrique par l'Empire du Japon by Ch. Ed. Guillaume (*C.R.* 1921, p. 795).

A telegram from Mr. Shirio Kikkawa, director of the Bureau of Standards of Tokyo, announces that the Japanese Parliament has passed a law making the use of the Metric System obligatory all over the Japanese Empire.

Mr. Guillaume mentions also that such a law was adopted in Siam in 1912 and that the Chinese, in 1908, having adopted a uniform system of measures all through their Empire, also gave the metric values of their units of measure.

F. H.

The Royal Astronomical Society of Canada

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